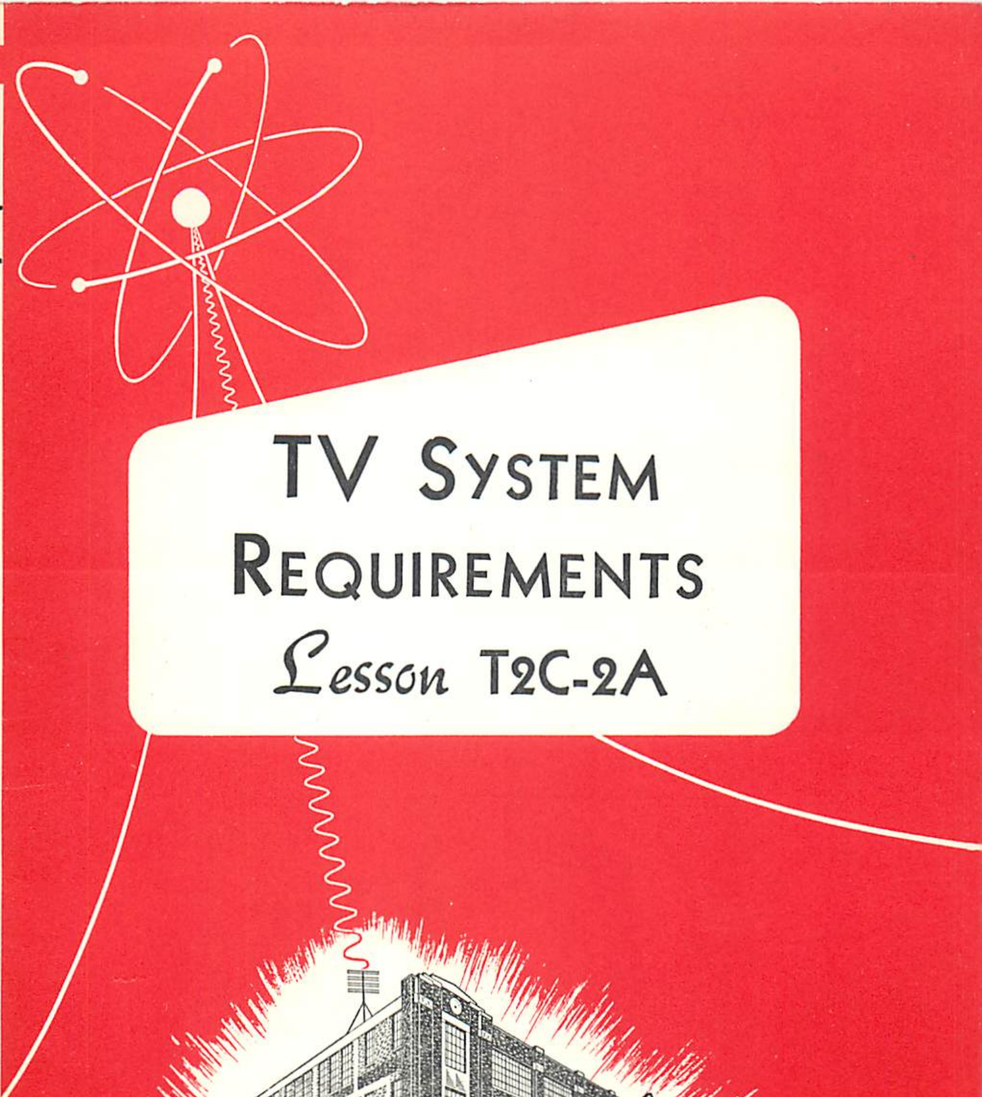


# TV SYSTEM REQUIREMENTS

## *Lesson* T2C-2A

**DeVRY Technical Institute**

4141 W. Belmont Ave., Chicago 41, Illinois

*Formerly* DeFOREST'S TRAINING, INC.

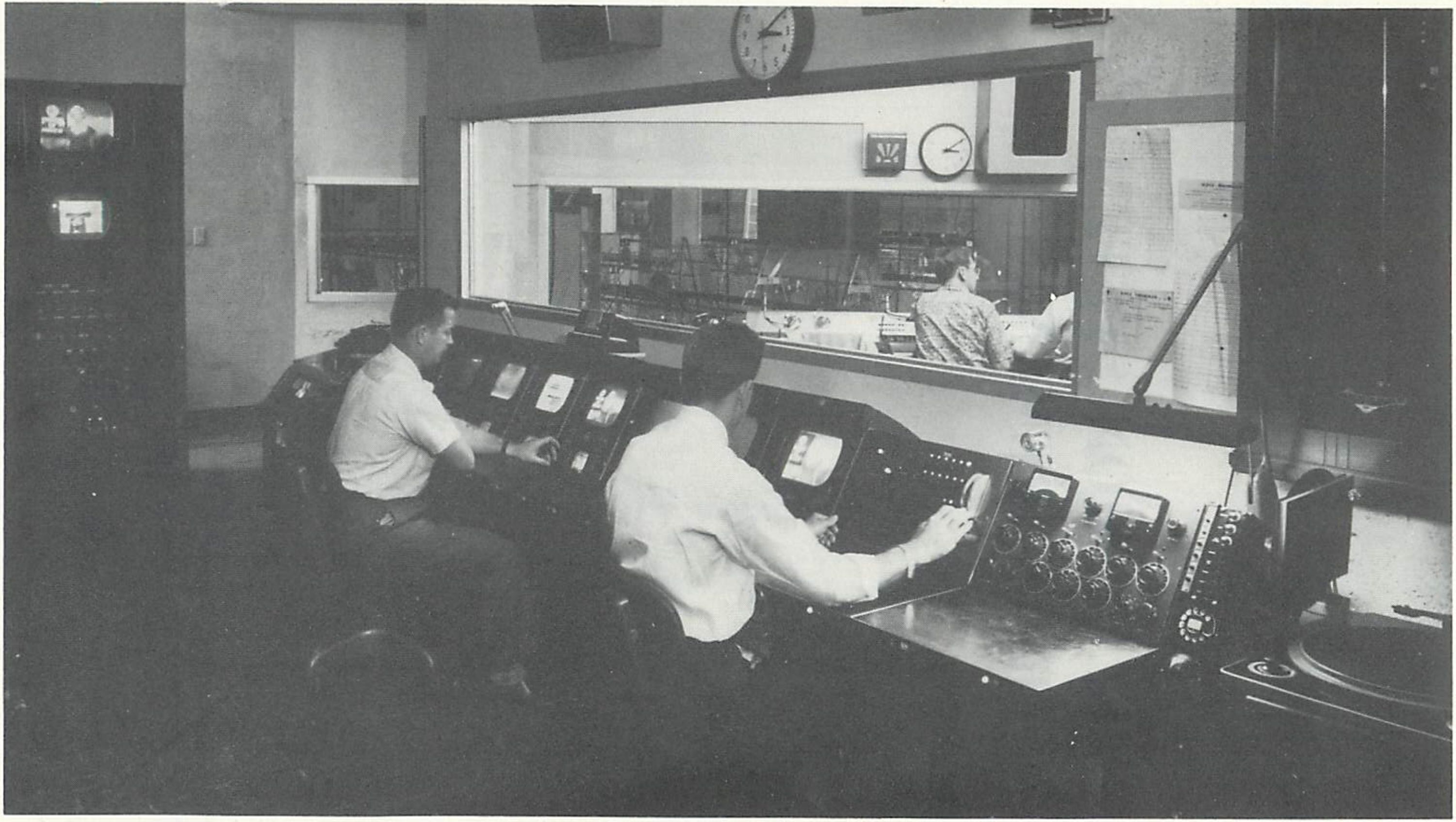
T2C-2A

# TELEVISION SYSTEM REQUIREMENTS

ELECTRONICS
TELEVISION
DTI
DeVRY Technical Institute

4141 Belmont Ave.
Chicago 41, Illinois

COPYRIGHT 1956



The master control room for the studios of this station. Studio "A" control room is in the background.

Courtesy WTVJ—Miami

# TELEVISION SYSTEM REQUIREMENTS

## *Contents*

PAGE
The Television Transmitter ........ 4
    The Picture Signal Path ........ 4
    The Sound Signal Path ........ 5
Television Channel Arrangement ........ 6
    The Video Transmitter Carrier ........ 6
    Vestigial Sideband Transmission ........ 7
    The Sound Transmitter Carrier ........ 8
Television Channel Allocations ........ 9
The Television Raster ........ 9
    Line Sequential Action ........ 9
    Interlace Scanning ........ 11
    The Scanning Frequencies ........ 14
    Aspect Ratio ........ 15
The Composite Video Signal ........ 15
Modulation Requirements ........ 16
The Television Receiver ........ 20
    Dual Channel ........ 20
    Modified Dual Channel ........ 21
    Intercarrier ........ 22

**Sound thinking is a term used to describe the mental activities of those who agree with us.**
**—Boston Globe**

# TELEVISION SYSTEM REQUIREMENTS

The television system, in transmission and reception, is basically only a special form of radio communication. For any particular television station, the accompanying audio of the picture incorporates most of the usual broadcast procedure of FM transmission; while the picture signal information is handled by AM transmission. However, as will be seen later, the complete signal for picture reproduction incorporates a much broader scope of modulating intelligence than only the picture element variations.

Because of these complex signal requirements, a group of engineers and other qualified persons, called the National Television System Committee (NTSC), formulated a set of television standards in 1940 suitable for a national system of television broadcasting.

Standardization of the television system was necessary in order to provide for reception of the image sent from any transmitter by any receiver within range. Produced by different manufacturers, all television transmitters and receivers must operate with the same scanning process, the same number of pictures per second, the same number of scanning lines per picture, etc. Until these important items were agreed upon by the members of the industry, the FCC could not permit television broadcasting on a commercial basis.

Officially adopted by the FCC, the "National Television System Standards" went into effect allowing commercial black-and-white or **monochrome** television broadcasting after July 1, 1941. More recently NTSC has formulated a compatible color television system which was adopted by the FCC on December 17, 1953. This system provides the standards for all color television broadcasts which are basically only additions to the monochrome standards. From this, it can be recognized that a working knowledge of the compatible color system first requires a complete understanding of the monochrome system.

## THE TELEVISION TRANSMITTER

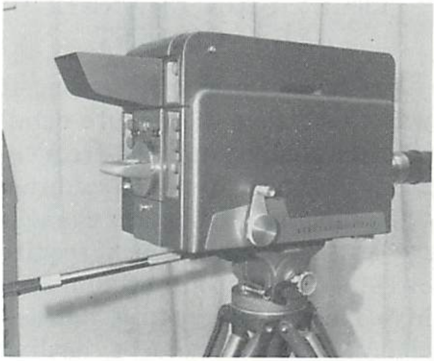
The general system arrangement for television transmission is shown in the block diagram of Figure 1. As can be seen, there are two completely separate transmitters—one for the sound signals and the other one for the picture and synchronizing pulse signals.

### The Picture Signal Path

As shown in the fundamental block arrangement, the main signal path for the picture information starts from the camera tube and goes through the camera preamp and interconnecting cable to the control amplifier, and from there to the studio control switches. Here the synchronizing and blanking pulses from the pulse generator are added to the picture information to form the complete picture signal which is referred to as the **composite video signal,** a small portion of which is shown as the wave-form going to the main video amplifier in the block diagram. The pulses of the signal finally control the beam deflection system in all television receivers tuned to the particular station. It will be noted that these same synchronizing and blanking pulses from the Pulse or Timing Generator are shown basically as also controlling the camera beam deflection system.

In order that the picture which is scanned by the camera can be continually checked and controlled, picture tube monitors are used at various picture signal points. One such monitor, with approximately a 5 to 7 inch tube, is mounted in a unit on top of the camera for viewing by the cameraman. Other monitors with larger picture tubes are found at the camera control amplifier and central studio control.

Since a number of cameras usually are involved in televising most programs to obtain proper angle shots, close-ups, etc., the studio switcher makes it possible to choose the desired picture to be used at that moment from the selection of pictures on the studio monitors, and sends this signal into the main transmitter circuits for modulation. Thus, the final composite video signal goes through the main video amplifiers to the AM transmitter modulator. From there the composite video amplitude modulated radio frequency signals go through the amplifiers to the antenna system for transmission.



A modern television camera. The cameraman's controls can be seen mounted in slots to protect them against accidental changes. The monitor picture tube face is shaded for viewing ease by the protruding hood.

Courtesy General Electric Co.

## The Sound Signal Path

As can be seen from the block diagram of Figure 1, the accompanying sound of the televised scene starts at the microphone and goes through the sound amplifiers and console control circuits to an FM transmitter; from there the Modulated Audio Carrier goes into the antenna system for transmission.

## TELEVISION CHANNEL ARRANGEMENT

From the previous lesson, it was found that the picture detail information contained frequencies up to over 4 mc. In addition to amplifying elementary changes for picture detail which require circuits with good medium and high frequency response, lighting changes and contrasts dealing with picture illumination require good low frequency response characteristics in the television circuits. These low frequency signals extend down to 30 cps and below. Thus the basic picture signal frequency range is from approximately 30 cps on the low frequency end to over 4 mc on the high frequency end. This is the approximate range of frequencies that modulates the television transmitter and finally is received and applied into the control grid circuit of the receiver picture tube to control the beam intensity.

The extremely broad bandwidth of the basic information for one picture can be even more appreciated when it is realized that this picture frequency range, from practically 0 to approximately 4.2 mc, covers a vast spectrum including the audio, AM broadcast, police, and low frequency short wave bands. Incidentally, this picture signal broad band requirement is the very reason why the television station transmitters are allocated channels in the UHF and VHF frequency spectrums.

In AM audio broadcasting, the basic audio information extends from approximately 0 to only 5 kc. It is recalled that in AM radio broadcasting, the carrier, being modulated by the maximum 5 kc of audio, produced equal sidebands of 5 kc above and 5 kc below the r-f carrier, and so required a station channel width of 10 kc, or .01 mc.

### The Video Transmitter Carrier

The FCC standard designates that THE VIDEO R-F CARRIER SHALL BE AMPLITUDE MODULATED. Like in AM radio transmission, sidebands are produced when the television video carrier is modulated by the composite video signal. Since the maximum picture signal frequencies that modulate the television carrier are over 4 mc, equal sidebands of a television carrier arrangement as shown in Figure 2A would produce a total channel width of almost 9 mc which is quite a difference as compared to the .01

mc width of AM audio transmission.

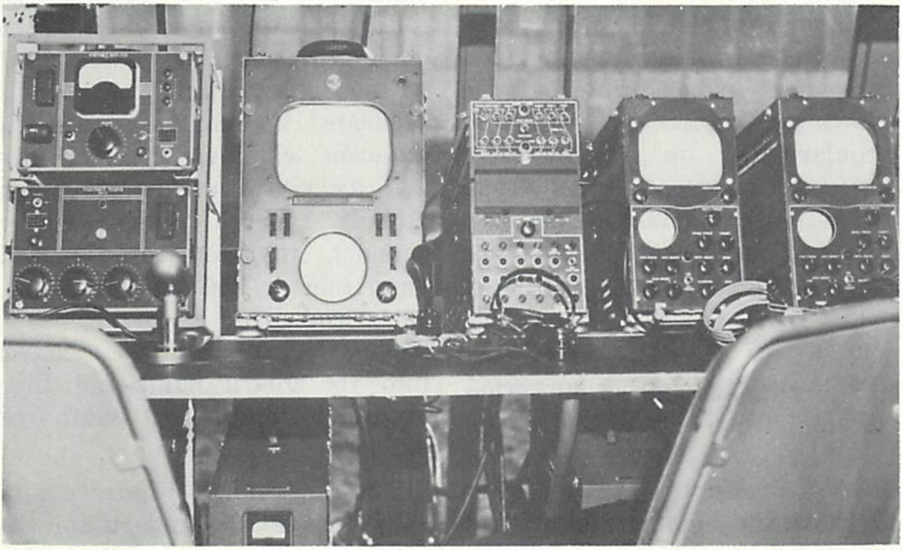
A channel width of this nature for one station, although a possibility, would be impractical and somewhat difficult and expensive to incorporate in both transmitter and receiver. BECAUSE A DUPLICATION OF THE MODULATING FREQUENCIES APPEARS IN BOTH SIDEBANDS, COMPLETE DOUBLE SIDEBAND TRANSMISSION IN AM IS UNNECESSARY, and is actually a wasteful system insofar as channel width is concerned.

### Vestigial Sideband Transmission

A slightly altered AM transmission method is used to reduce the channel width requirement mentioned for the picture transmitter. The basic channel arrangement of the method adopted is shown in Figure 2B. It provides sideband space for the over 4 mc of modulating intelligence for the picture r-f signal plus some additional space which can accommodate the sound transmitter signal.

As indicated by the diagram, all of the upper sideband frequencies and only a portion of the lower sideband frequencies are transmitted. This arrangement is known as **vestigial sideband transmission.**

This vestigial sideband result is achieved by the use of a filter which is actually a tuned LC circuit. A part of this circuit is shown in the diagram of Figure



Portable television camera equipment used for sports and news events. Two camera control units with monitors for two television cameras can be seen at the right.

Courtesy of Sylvania Electric Products, Inc.

3; attention is called to its position in the block diagram of Figure 1. This filter, made up in part of L, $L_1$, and C in Figure 3, acts like a trap to "by-pass" or attenuate most of the lower sideband frequencies.

Thus, the location of the video r-f carrier quite some distance to the left of the center of a specified channel is made possible, and permits enough space for the complete upper sideband of frequencies to be transmitted. Part of the small remaining space is used by the sound transmitter. Some of the lower sideband frequencies are transmitted because serious phase distortion would result if only a single sideband transmission were used.

A more complete diagram showing the television channel arrangement and characteristics is shown in Figure 4. The actual standard set up by the FCC DESIGNATES THAT THE VIDEO TRANSMITTER CARRIER BE LOCATED 1.25 MC UP FROM THE LOWER LIMIT OF THE CHANNEL, and THAT EACH STATION HAVE A CHANNEL WIDTH OF 6 MC.

The standard also specifies that the amplitude of the sideband frequencies be down to .05 of 1% of maximum at the lower limit of the channel to prevent interference with another station that is adjacent. It also states that the upper sideband amplitude be down to the same low percentage at a point that is 4.5 mc above the video carrier to prevent interference with its own sound transmitter.

## The Sound Transmitter Carrier

The FCC standard designates that THE SOUND R-F CARRIER SHALL BE FREQUENCY MODULATED. Unlike the FM sound broadcast station carrier, 100% modulation for the television sound carrier is defined as being ±25 kc. As can be seen in Figure 4, the standard frequency location for THE EXACT CENTER OF THE FM SOUND CARRIER HAS BEEN DESIGNATED at a frequency distance of 4.5 MC ABOVE THE VIDEO CARRIER LOCATION. The small remaining space between the sound transmitter and the upper limit of the channel is sometimes referred to as the **guard band,** because it separates the channel from the adjacent channel above. Since 1.25 mc + 4.5 mc, or 5.75 mc is already covered in the 6 mc channel, the remaining guard band then is 250 kc, or .25 mc. When the sound carrier is 100% modulated, it deviates ±25 kc into the guard band and thus leaves a minimum width of 225 kc.

The diagram of Figure 4 also shows the FCC standard for the color carrier position. How this carrier is used is described later in the color television lessons.

## TELEVISION CHANNEL ALLOCATIONS

As we mentioned before, that because of the broad band requirements for each television station, the channel carrier frequencies were assigned by the FCC to the VHF and UHF spectrum. As can be seen in Chart 1 at the back of the lesson, the Federal Communications Commission has allocated 82 six-megacycle channels for television broadcasting. The twelve VHF channels are between 54 and 216 mc, and the seventy UHF channels extend from 470 to 890 mc. Channel 1 is no longer available for television, and has been reallocated for other services.

In addition to the 82 broadcast channels listed in this chart, the FCC also assigns auxiliary channels for remote pickups, studio to transmitter (STL), and for intercity television relay. These allocations occur between 1990 and 2120 mc, 6875 to 7050 mc, and from 13025 to 13200 mc. Finally, sound channels for relay purposes are provided between 890.5 to 910.5 mc for the sound portion of a television program or communications relating thereto.

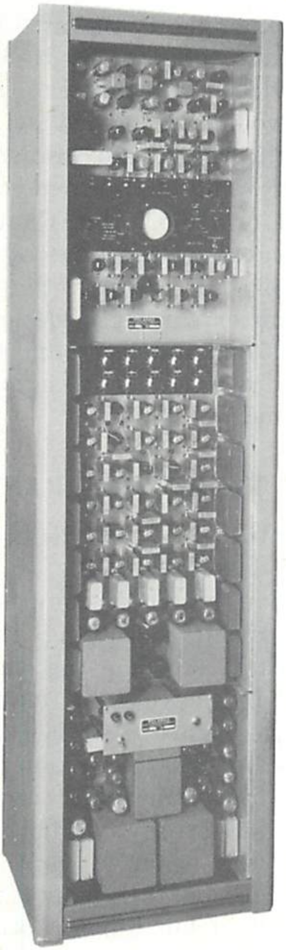
In obtaining a more practical relationship between the assigned frequencies and the typical channel arrangement of Figure 4, a closer study of particular station channels can be made. Channel 3, for example, is allocated in the frequency range of 60 to 66 mc. The video transmitter carrier then would be located at 61.25 mc, and the sound transmitter carrier would be located 4.5 mc higher, or at 65.75 mc. Channel 4 is allocated in the range of 66-72 mc. For this station, the video transmitter carrier is designated at 67.25 mc and the sound transmitter carrier is assigned to 71.75 mc.

## THE TELEVISION RASTER

According to our description in the last lesson, the standard television raster is composed of 525 horizontal scanning lines. A more exact sketch of the scanning action is shown in a magnified form in Figure 5. It is recalled, that beam scanning action is produced by a horizontal and vertical deflection system which causes the beam to go through many horizontal lines as it moves gradually from top to bottom.

### Line Sequential Action

As can be seen in Figure 5, the slow uniform vertical motion actually puts a slant on all the scanning lines. Comparatively speaking, the beam moves slowly and uniformly to the right side for the line trace period and then quickly returns to the left side in the retrace time. During this time



To develop the standard blanking and synchronizing pulses for the television signal, a pulse generator of this or similar types is required in each station.

Courtesy Polarad Electronics Corporation

for horizontal trace and retrace, the beam has also been gradually moving downward. As pictured in Figure 5, compared to the left-to-right movement, the horizontal return period of the spot is of very short duration; therefore, as indicated, very little vertical distance is then covered.

The FCC standard states that during active scanning intervals THE SCENE SHALL BE SCANNED from left to right horizontally and from top to bottom vertically AT UNIFORM VELOCITIES. This uniform velocity is exemplified for the horizontal deflection system in the actual sawtooth deflection wave-form visible for each line when looking at Figure 5 on its edge. Of course, with the great quantity of lines used in the standard system, the distance between each line is extremely small; and the individual trace—retrace wave-form is not easily distinguishable in the raster, but it does exist.

This sawtooth deflection wave-form which is used to deflect the beam, thus developing the raster, is produced in special deflection generator circuits. The resulting wave-form then is applied at the picture tube as either a sawtooth current or sawtooth voltage wave-form, depending upon the method of deflection employed.

A sawtooth current is used when a picture or camera tube requires a deflection yoke, mounted around the outside of its neck, for magnetically deflecting the beam; and a sawtooth voltage is used when a tube has deflection plates, mounted in the inside, for a deflection method referred to as static deflection of the beam.

As will be noticed in Figure 5, the long period part of the sawtooth is the heavy horizontal trace line, and the short time period is the light retrace line. In all cases, either sawtooth deflection voltages or currents are employed for this beam scanning system at the television camera and receivers. Only this unidirectional linear scanning method produces an even distribution of illumination and detail, is easy to synchronize, and makes full use of the video bandwidth. All other possible methods, such as bi-directional, sinusoidal, and spiral scanning, are each characterized by a lack of one or more of these qualities.

At the end of each linear trace time, a pulse signal arrangement from the transmitter timing generator blanks out the beam intensity at the camera and receivers, and triggers or synchronizes the respective deflection systems into retrace action. This action then invisibly returns the beam for the beginning of the next trace period.

When the vertical sawtooth deflection system finally gets the scanning lines down to the bottom of the raster, it is caused to retrace quickly back to the top of the raster to start another complete scanning sequence. In this vertical retrace period, a timing generator pulse arrangement blanks out the beam intensity and triggers or synchronizes the vertical deflection system into retrace action.

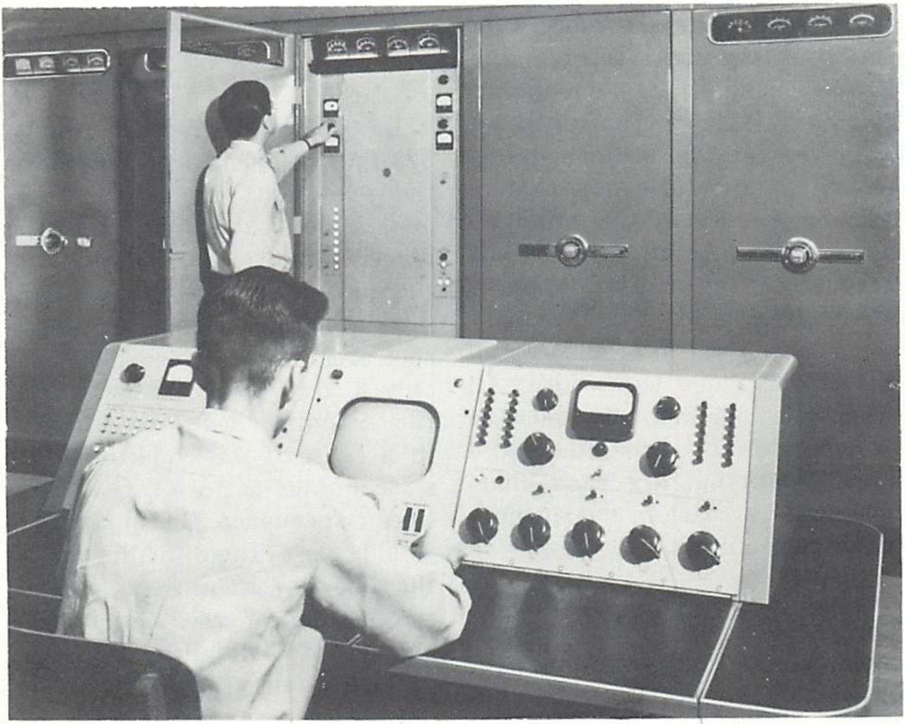
### Interlace Scanning

In spite of the fact that thirty 525-line patterns are placed on the television screen every second, a noticeable, eye fatiguing flicker would still result without the added arrangement of line interlace. Each elementary beam spot area of the screen glows for only a very short interval after the scanning beam passes over it. Because of this condition, with a scanning pattern of all 525 lines in sequence, the upper lines would loose their brilliance by the time the scanning spot reached the bottom of the raster. This change of brilliance for every pattern would produce the flicker.

To reduce this flicker, the vertical deflection speed of the beam is doubled to produce an interlaced 525-line raster similar to the simplified sketch of the interlaced 11-line raster shown in Figure 6A.

In this illustration, the spot is shown having a greatly exaggerated diameter. The various positions of the spot are indicated by the circles such as those marked 1, 15, 3, etc., at the left edge and those marked 14, 16, 2, etc., at the right edge of the raster. In addition, the 11 scanning lines are numbered from the top to the bottom of the raster on the outside edges. The shaded T areas are the small parts of the screen not covered by the scanning spot.

Starting at position (1) in the upper left-hand corner, the beam spot moves to position (2), tracing out the top scanning line number 1. During this left-to-right movement, the spot travels downward also, for a distance equal to twice its diameter. Consequently, after retracing rapidly from position (2) to position (3), it is ready to trace scanning line number 3, to position (4), having skipped scanning line number 2. After moving to position (5), it scans lines 5, 7, 9, and the first half of 11 in order, having skipped lines 4, 6, 8, and 10.



The television station includes two complete and separate transmitter units, one for sound and the other for the picture information.

Courtesy Federal Telecommunication Labs., Inc.

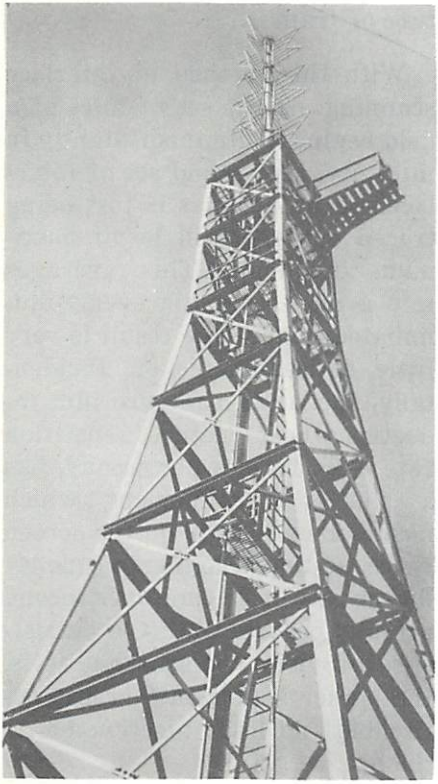
At the middle of line number 11, which is position (12), the beam has reached the end of vertical deflection and is suddenly vertically retraced to position (13), at the top, where it completes the tracing of the eleventh scanning line. From position (13) to position (14), because the spot moves only halfway across the screen, it travels downward a distance equal only to its diameter. Therefore, retracing to the left side of the screen, it arrives in position (15), to begin scanning line number 2 which is "in-between" the lines scanned previously.

From position (15) to position (16), the spot traces line number 2 and again moves downward a distance equal to twice its diameter, so that retracing to position (17), it is ready to scan line 4. In similar manner, lines 6, 8, and 10 are scanned with lines 3, 5, 7, and 9 being skipped. Reaching the end of line 10 at position (24), the beam is again at the end of vertical deflection and so retraces to position (1) in the upper left-hand corner of the screen, ready to begin another frame.

Thus, in this interlace scanning arrangement, in order to trace out all the lines of the raster once, the beam spot completes 2 vertical cycles of deflection. During one vertical scan in Figure 6, the beam traces out 5½ lines, and on the second vertical cycle traces out the other 5½ lines which then completes one frame. Each vertical scan period is referred to as a **field**, and thus it takes 2 fields to completely scan all the horizontal lines for one complete picture or frame.

With this method of interlace scanning, as one set of lines of a field begins to diminish slightly in intensity, the second set of interlaced scanning lines is just being traced out and will be at maximum brilliance. This averages into a more over all, evenly-illuminated frame. The result is very little noticeable flicker. Incidentally, the motion picture film industry whose picture repetition rate is 24 frames per second, has a shutter arrangement which flashes each picture on the screen twice, so that a higher frequency flicker rate of 48 times per second actually occurs. With the persistence of vision being what it is, the higher flicker rate is less noticeable and less objectionable to the eye.

The result of interlace action is obtained only if an odd number of scanning lines is used in the raster structure. Figure 6B, composed of 5 horizontal sawtooth deflection cycles, represents the time for one frame of odd lines. Dividing line h represents the bottom of one field and the top of the next. The result of splitting the odd number 5, in two at h will leave the half line condition as shown. Whether that odd number of lines used is 5 or 525, the half line condition will always occur at the split.



A television transmitting antenna located over 600 feet above the ground. The effective radiated power is 142,500 watts for the video carrier and 94,500 watts for the sound carrier.

Since dividing an odd number of lines by two will always result in a half line left over, the beam will end at, and start from a different point on the raster for each successive vertical scan or field like the diagram of Figure 6A shows. An even number of lines divided into two fields would always have the beam finish and start on a full line. Notice that the bottom and top limits of the raster are the same for both fields as shown in Figure 6A. An even-numbered line raster arrangement therefore, would make interlace action impossible; the fields would overlap rather than interlace.

Accordingly, the FCC standard for the television system designates 525 LINES PER FRAME INTERLACED, 2 TO 1, IN SUCCESSIVE FIELDS and that, nominally, 60 FIELDS BE SCANNED IN ONE SECOND. This affords a flicker frequency of 60 times per second, and requires the beam to travel from the top to the bottom of the raster in about 1/60 of a second. Since it takes 2 fields to make up one frame, 60 ÷ 2 equals 30 frames per second.

In one vertical scan or field, 525 ÷ 2, or 262½ horizontal lines will be traced out; in the next field, the "in-between" 262½ lines will be scanned. This completes one 525-line frame in 2/60, or 1/30 of a second, and is similar to the 11-line arrangement of Figure 6A or the 5-line time sketch of Figure 6B.

### The Scanning Frequencies

Since 262½ raster lines are scanned every field, with 60 fields per second there are 60 × 262½ or 15,750 horizontal lines traced out each second. This means that the frequency of the horizontal sawtooth deflection system must be 15,750 cycles per second, while the frequency of the vertical sawtooth deflection system is 60 cycles per second.

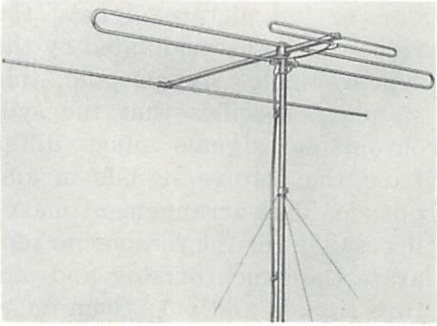
However, a more exact set of standard deflection frequencies is required for color transmission. The actual value set for the vertical deflection frequency is 59.94 cps, and 15,734.264 ± 0.044 cps for the horizontal deflection frequency. These values are so close to the original monochrome standards that they effect no change for **compatible reception** quality in the monochrome receiver. In fact, THE FCC STANDARD goes on to state, that FOR MONOCHROME TRANSMISSION, THE NOMINAL DEFLECTION RATES of 60 CPS FOR THE VERTICAL and 15,750 CPS FOR THE HORIZONTAL MAY BE USED. These easier to remember nominal values will be referred to in most of our descriptions of the television system.

### Aspect Ratio

It has been mentioned that the raster has a width to height dimension relationship of 4 to 3. This is referred to as the **aspect ratio** of the picture. The FCC standard states that the ASPECT RATIO of the transmitted picture shall be 4 UNITS HORIZONTALLY FOR EVERY 3 UNITS VERTICALLY. Thus, if a television receiver picture were $12\frac{3}{4}$ inches high, it would be 12.75 × 4/3, or 17 inches wide.

## THE COMPOSITE VIDEO SIGNAL

In order to properly develop the camera and receiver rasters and maintain exact synchronism between them, an additional signal of pulses is combined with the picture signal variations to form what is termed the composite video signal. The FCC standard regarding the synchronizing signals states that **a carrier shall be modulated within a single television channel for both picture and synchronizing signals. For monochrome transmission, the two signals comprise different modulation ranges in amplitude, in accordance with the charts designated as Appendix III, Figures 3 and 4 (b).**



A typical VHF receiving antenna made to receive all of the channels from 2 through 13.
Courtesy American Phenolic Corporation

The "Figures 3 and 4" referred to in the official wording of this standard is shown here as Figures 4 and 7, respectively. Including the PICTURE SIGNAL, BLANKING PULSES, and SYNCHRONIZING PULSES: this is the wave-form of the complete video signal which modulates the video carrier at the transmitter. Neglecting any distortion, this same wave-form is reproduced in the receiver video amplifier stages which follow the video detector.

As shown in Figure 7, in addition to the picture signals, the video carrier is modulated by the synchronizing signals and this standard specifies that the synchronizing signals must differ from the picture signals in amplitude. This arrangement makes it possible for the receiver to separate the synchronizing and picture signals and pass them on to the proper circuits. The exact nature of the synchronizing signal is specified in a later standard.

Starting at the left, the curves of Figure 7 represent a few lines at the end of one field, the vertical retrace time, and a few lines at the beginning of the next field. The larger central portion of the curves represent the video waveform during the time that the electron beam is returning from the bottom to the top of the screen. This is the portion labeled VERTICAL BLANKING PULSE in Figure 7A and, although not labeled, it occupies a similar portion of Figure 7B.

The vertical blanking pulse of the signal is really a relatively long, rectangular or "square" pulse, on top of which are superimposed the various shaped synchronizing pulses. Though only a few lines are shown preceding and following the vertical blanking pulses, actually there are approximately 240 of them in each field.

Occurring during the line scanning periods, the picture signal is shown between the HORIZONTAL BLANKING PULSES at each side of the drawing. The horizontal blanking pulses occur during the horizontal retrace movement of the beam to reduce the spot brilliance to the black level so that the retrace lines are not seen on the screen. The narrow horizontal synchronizing pulses which control the frequency of the horizontal deflection generator are superimposed on top of these blanking pulses.

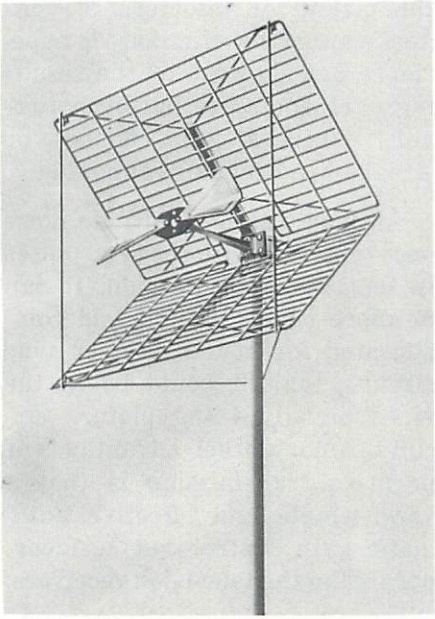
## MODULATION REQUIREMENTS

The polarity and amplitude proportion of the composite video signal shown in Figure 7 is that which is observed when modulating the transmitter. The FCC standard for transmitter modulation is that, A DECREASE IN INITIAL LIGHT INTENSITY SHALL CAUSE AN INCREASE IN RADIATED POWER. The indicated polarity of the composite signal of Figure 7 conforms to this requirement if applied correctly to the modulator. Maximum amplitude of the carrier signal should then occur during the blanking and sync pulse periods, and a relatively high amplitude carrier level is also set for the black signal reference of the picture. The picture information itself, which is a variation of light intensity, is at a lower carrier amplitude level.

The modulated carrier radiating from the transmitter antenna is illustrated for about one line of composite video signal in Figure 8, and shows the modulation result of the indicated polarity of Figure 7. Since white is opposite from black, it appears at the low amplitude level marked in the corresponding signal waveforms of Figures 7 and 8.

Thus, any reduction in light intensity, or APPEARANCE OF DARK PICTURE ELEMENTS, immediately CAUSES AN INCREASE IN TRANSMITTER OUTPUT: while any increase in light intensity, or appearance of white picture elements, will immediately cause a decrease in transmitter output. This modulation effect is termed **negative transmission** because black produces maximum output, while white produces minimum output.

The receiver is arranged with a number of amplifier stages used so that the final composite video signal polarity is such that the blanking pulses will drive the picture tube into cutoff to darken the screen for retrace action. The picture information, which originally caused a lower carrier amplitude, will now have a final polarity in the receiver to cause the picture tube screen to be illuminated directly proportional to the brightness of the original picture elements.



A typical UHF receiving antenna for channels 14 to 83.

Courtesy JFD Mfg. Co., Inc.

Insofar as the transmission of video signals is concerned, the opposite method, "positive transmission," might have been employed, but negative transmission was selected. Any undesired r-f energy (such as automobile ignition interference) adds itself to the signal from the transmitting station, and causes an increase in total signal strength at the receiver.

With positive transmission, this increase in signal would cause light spots, flashes, or streaks on the screen, but, with negative transmission, the increase in signal results in dark spots. When the pickup of interference voltages cannot be eliminated, experience has shown that the resulting dark spots are hardly noticeable, whereas light flashes or streaks are decidedly annoying.

Although high amplitude noise does interfere with the sync pulses in negative transmission, it can be more easily limited and compensated for in the receiver sync circuits than it could be in the video signal of the picture circuits. Among other advantages of negative transmission is that a very simple and effective automatic gain control can be incorporated in the television receivers.

The FCC standards for definite amplitudes in the composite signal relating to the various brightness levels of the picture information are clearly marked in Figure 8, such as the **reference black level.** On the television receiver screen, it is important that all objects or areas of any particular light or shade be reproduced with the same relative values of light intensity each time they appear. The intensity of the light produced by the scanning spot depends upon the signal voltage applied to the control grid circuit of the picture tube, therefore, a definite level of signal amplitude must be established. Because the relative brightness of various parts of a reproduced image can be evaluated only by comparison, a reference level or comparison starting point has been set at that signal which "cuts off" the electron beam.

With the beam cut off, the scanning spot does not illuminate the screen and thus produces a black element or area. To cause this condition, the signal output of the transmitter must always rise to the same definite level each time a black area is scanned. This is known as the reference black level, and must be independent of other values of light and shade in the picture. In proportion to the peak signal, this level is set at approximately 70% of maximum amplitude by the action of the DC restorer arrangement at the transmitter.

Since the white picture elements cause the carrier amplitude to approach zero, a **reference white level** of approximately 12½% of peak carrier was established by the FCC, so that carrier power would not be dropped too low. This limit was put into effect in most monochrome stations before its standard was adopted, because it protected the quality of sound reception in a certain type of television receiver application. This reference is an even more critical requisite for the picture information in good color reproduction.

The **blanking level** for the proper amplitude of the blanking pulses was established at approximately 75% of the peak carrier amplitude. Besides insuring a high enough blanking pulse amplitude for good cutoff conditions during retrace periods at the receiver picture tube, the established percentage also prevents these pulses from going too high and reducing the proportion of the sync pulses.

In order to provide for proper separation or clipping of the sync pulses in the sync circuits of the television receiver, the sync pulses extend to a higher amplitude than any other portion of the composite signal.

THE OUTPUT OF EACH TRANSMITTER IS SET BY THE FCC IN TERMS OF PEAK POWER, AND THE TOPS OF THE SYNC PULSES ARE THE ONLY PARTS OF THE COMPOSITE SIGNAL WHICH CAUSE THE CARRIER TO REACH PEAK POWER. Thus, under normal conditions, the sync pulses modulate a maximum of 25% of the total carrier amplitude, and exist between the 75% and 100% carrier amplitude levels.

If the blanking pulses were allowed to go higher than their established amplitude, the proportional amplitude of the sync pulses would be reduced; for example, if the blanking level were allowed to rise to 90% of peak carrier, then, only a 10% proportion would remain for the sync pulses. This reduced sync amplitude could seriously affect the sync circuitry in television receivers.

This monochrome television receiver uses the intercarrier type circuit arrangement. The standard compatible television signal permits the receiver to reproduce a monochrome picture from a color signal.

Courtesy Motorola, Inc.

Since any signal amplitude higher than the reference black level will continue to keep the picture tube screen dark, the synchronizing pulses, having amplitudes greater than the black level, are located in what is called the **ultra black** or blacker-than-black region.

Thus, the final result of all the specifications presented, is a national system which provides a uniform composite video signal and modulation arrangement as shown in Figures 7 and 8, that is transmitted by all stations, and able to be received by all standard makes and models of television receivers for picture reproduction.

## THE TELEVISION RECEIVER

Basically, a large portion of the television receiver can be compared with a radio receiver. In actuality, it is a high-frequency, broadband, superhet receiver which provides signal paths for the sound, picture, and sync information transmitted from the television station for application to the speaker, picture tube, and deflection systems of the television receiver.

Several different receiver signal-path arrangements are used in the method of getting the various signals to the points mentioned in the receiver. They include the dual channel, the modified dual channel, and the intercarrier.

### Dual Channel

In Figure 9, is a block diagram of a dual channel television receiver. Both the sound carrier and picture carrier are received by one broad band antenna system and applied to the television tuner which is also a broad band unit. As can be seen, the tuner section conforms to the basic superhet arrangement used in radio receivers, which includes the r-f amplifiers, local oscillator, and mixer. The sound and picture r-f signals are both amplified by the one r-f section and coupled to the mixer section where the local oscillator signal is also applied.

Since, in a television system, the local oscillator beats with two r-f carriers, then two i-f signals at the same distance from each other will be the result—the sound i-f and the picture or video i-f. Several different intermediate frequency ranges (20 mc, 30 mc and 40 mc) are being used by receiver manufacturers. The 40 mc range is used in this example, and so, the two i-f signals at the output of the mixer are indicated as being 41.25 mc for the sound i-f and 45.75 for the video i-f.

Notice, that immediately there are two separate signal paths—one for the sound i-f and one for the video i-f. Since the sound signal and video signal are routed into completely separate paths or channels after the mixer circuit, this receiver system is referred to as a dual channel arrangement.

As shown in Figure 9, the path of the sound signal here is identical to that of a radio receiver, in that it goes through the i-f amplifier section, the detector, and the audio circuits to the speaker.

The video signal takes a similar route through its channel, which includes the i-f amplifiers, the detector and the video amplifiers, with the signal finally being applied to the grid circuit of the picture tube. The required bandwidth of this circuit, however, is much broader than that for the sound channel.

Another path for the composite video signal goes from the video amplifier section to the sync circuits which control the deflection system. As is shown in Figure 9, the composite signal is coupled to the sync clipper where all the picture and blanking signals are removed. Thus only the sync pulses, because of their high amplitude characteristic, appear in the output of the clipper circuit. From there, the sync pulses are amplified and applied through the proper RC networks to synchronize the horizontal and vertical deflection systems for developing the proper raster on the picture tube.

With the addition of the low voltage and high voltage sections briefly indicated on the diagram, the basic description of an entire television receiver is complete.

### Modified Dual Channel

The modified dual channel receiver is what its name implies—a modification of the original dual channel arrangement. Figure 10 includes that portion of this receiver which is involved in the change from the dual channel.

The first difference exists in the output of the television tuner; where now, one lead couples both the sound and video i-f signals to a common i-f amplifier. This provision removes a circuit from the tuner assembly making it a more compact and practical unit.

As shown in Figure 10, the sound i-f take-off circuit may couple from anywhere in the i-f amplifier sections to the sound i-f amplifiers. Another advantage of modified dual channel lies in the fact that usually one less amplifier is required for the sound i-f section.

In summary, this system is defined as an arrangement where the sound i-f channel takes off from a point somewhere after a common i-f amplifier but before the video detector. With these slight alterations, the remainder of this type receiver is completely identical to the one in Figure 9.

A color television receiver. The standard compatible television signal permits this receiver to reproduce pictures in either color or monochrome.

Courtesy Sentinel Radio Corporation

### Intercarrier

The intercarrier type of television receiver has many advantages, and is the most popular one manufactured today. In fact, this basic arrangement is used both in monochrome and color receivers. Figure 11 includes that portion of this type of receiver which differs from the first two receivers described.

It is recalled from Figure 4, that, in the standard requirement at the transmitter, the difference in frequency between the sound r-f carrier and the video r-f carrier was set at 4.5 mc. Thus, attention is called to the fact that, in all cases in the receiver block diagrams shown, the difference between the sound i-f and video i-f carrier frequencies always is 4.5 mc, which, here, is 45.75 mc – 41.25 mc.

For the Intercarrier arrangement of Figure 11, it can be seen that the entire i-f amplifier section between the tuner and the video detector is common to both the sound and video i-f's. Again, only one lead is required from the tuner, which incidentally, makes the TV tuners of Figure 10 and Figure 11 interchangeable.

As shown in Figure 11, both i-f carrier signals are applied into the video detector circuit. Since the video AM detector, usually a diode, is a non-linear device, it will not only detect the AM video signal for the picture information, but it will also cause a mixing action of the two carriers present.

This mixing is identical in action to any tuner arrangement, where a local oscillator carrier and a signal carrier or carriers are applied to the mixer stage. Any mixer stage is essentially a non-linear device that among other things, produces a beat difference frequency between the carriers applied, which is always referred to as the i-f.

Thus, as the sound and video i-f carriers are applied to the video detector, a beat difference output of 4.5 mc occurs because of the constant difference between the sound and video carrier frequencies at all television stations.

As a result, the FM sound i-f is now converted from 41.25 mc, in this case, down to 4.5 mc; while the AM video signal has been detected, and is ready to be amplified for the picture circuits.

Since the AM video detector cannot affect the frequency modulation in the 4.5 mc beat result, this 4.5 mc i-f signal still needs proper handling by an FM detector for the usual sound output.

A 4.5 mc tuned sound takeoff circuit is employed anywhere after the video detector and before the picture tube input. In Figure 11, this 4.5 mc sound signal is taken from one of the video amplifiers and applied to the 4.5 mc sound i-f circuits, where the FM detector finally applies the sound signal to the audio output section.

The term, intercarrier, comes from the fact that both sound and video signals have a path within, or common to the same sections of the receiver, from the tuner all the way through to the video detector mixing action and into the video amplifier circuits.

Besides the advantage in the intercarrier receiver system of fewer required stages, another advantage exists in sound signal stability. Should the local oscillator frequency in the TV tuner drift slightly, both resulting i-f signals will drift proportionately. However, the 4.5 mc difference between them remains. Thus the 4.5 mc beat frequency out of the video detector will never shift in frequency. This provides an optimum condition for the 4.5 mc tuned FM detector circuit and eliminates fading and distortion.

In the two dual channel systems mentioned, if the TV tuner local oscillator drifted ¼ mc higher, for example, the sound i-f would change to 41.50 and the VIF to 46.00 mc. Since the tuned circuits in both cases are tuned to 41.25 mc, the sound i-f signal would now be ¼ mc, or 250 kc away from the required circuit frequency. With the total FM band width only about 50 kc wide, this 250 kc shift would cause the sound i-f signal to go practically to zero resulting in low, distorted, or no sound output.

Notice, that in spite of the original oscillator drift mentioned, the difference between 46 mc and 41.5 mc is still 4.5 mc. Thus, the intercarrier receiver sound output would remain stable.

A double conversion actually exists for the sound signal carrier. The first conversion occurs in the tuner, and the second conversion takes place in the video detector. Thus, there always are two sound intermediate frequencies in an intercarrier type system with the 2nd signal fixed at 4.5 mc regardless of the tuner i-f range output or possible drift.

In a general examination of the receiver types, it can be seen that their basic difference exists in the starting point from which the sound signal takes its own individual path to the detector and audio output circuits. Except for this variation, the remainder of the circuits of these three types of receivers could be made identical.

This lesson has described the complete, basic television system from the transmitter through the receiver. Along with the preceding introductory material, it also affords a practical analysis of the composite video signal and its transmission characteristics.

It is the object of the television receiver to receive the television station signals, and handle them properly in order to reproduce the original picture and sound information.

The next lesson is the first of a series of lessons that concentrate on the individual receiver circuits.

Since the signal paths through the television receiver begin from the antenna input, the first part of the receiver in that signal path is the input section, referred to as the TUNER.

Because television tuners tune over such a vast band of high frequencies, they require special circuitry and physical arrangements. As a result, quite a few different tuner units have been made by various manufacturers.

In order to apply the various required servicing techniques to the television receiver, a service technician should become familiar with the general tuner circuits. Therefore, these are described in the next lesson.

## IMPORTANT DEFINITIONS

**ACTIVE SCANNING LINES**—Those visible scanning lines which occur between vertical blanking periods of a field.

**ASPECT RATIO**—The dimension ratio of the transmitted picture width to height.

**BLANKING LEVEL**—The 75% of peak carrier amplitude to which the horizontal and vertical blanking pulses rise.

**COMPATIBLE RECEPTION**—[k'm PAT i bil]—The ability of a monochrome television receiver to receive a color signal and reproduce a black and white picture without any circuit alteration, and for a color receiver to reproduce a black and white picture from a monochrome signal without any circuit alteration.

**COMPOSITE VIDEO SIGNAL**—[k'm PAHZ it VI dee oh]—The combined television signal made up of picture intelligence, blanking pulses, and horizontal and vertical sync pulses.

**EQUALIZING PULSES**—A group of 6 pulses in the vertical blanking period; one group of pulses precedes, and another group of pulses follows the vertical serrated sync pulse.

**FIELD**—One vertical deflection sequence of television picture scanning which occurs in approximately 1/60 of a second and consists of 262½ horizontal scanning lines that lie in-between the preceding or succeeding field of scanning lines.

**GUARD BAND**—A band width of 250 kc between the sound carrier reference and the upper frequency limit of each television channel to prevent interference between two adjacent channels.

**HORIZONTAL BLANKING PULSE**—The pulse which blanks out the camera and picture tube screens during the horizontal retrace interval.

**HORIZONTAL SYNC PULSE**—The pulse which triggers the horizontal deflection generators at the transmitter and receiver to keep them synchronized.

## IMPORTANT DEFINITIONS—(Continued)

**MONOCHROME**—[MA noh krohm]—Single color only; a picture reproduced in varying shades between black and white.

**NEGATIVE TRANSMISSION**—Where a decrease of light intensity in the television signal is represented by an increase of transmitted power.

**REFERENCE BLACK LEVEL**—The video carrier amplitude level of approximately 70% of peak which serves as the reference for signals representing the black elements of a picture.

**REFERENCE WHITE LEVEL**—The video carrier amplitude level of approximately 12.5% of peak which serves as the reference for signals representing the white elements of a picture. It is also the minimum level to which the transmitter carrier can extend at any time.

**SEQUENTIAL**—[si KWEN sh'l]—A process of successive order rather than simultaneously.

**ULTRA BLACK**—That portion of the television signal which is beyond the reference black level and extends through the sync pulse region. Any signal or noise in this Ultra Black region has no effect on the picture itself.

**VERTICAL BLANKING PULSE**—The pulse interval that blanks out the camera and picture tube rasters during which time vertical retrace occurs.

**VESTIGIAL SIDEBAND TRANSMISSION**—[ves TIJ i al]—A system of transmission wherein a portion of the frequencies in the lower sideband of the transmitter carrier are attenuated at the transmitter. Some of the sideband frequencies closer to the carrier reference are transmitted.

## TELEVISION BROADCAST CHANNELS

| CHANNEL | FREQUENCY IN MC | CHANNEL | FREQUENCY IN MC | CHANNEL | FREQUENCY IN MC | CHANNEL | FREQUENCY IN MC |
|---|---|---|---|---|---|---|---|
| 2 | 54– 60 | 23 | 524–530 | 44 | 650–656 | 65 | 776–782 |
| 3 | 60– 66 | 24 | 530–536 | 45 | 656–662 | 66 | 782–788 |
| 4 | 66– 72 | 25 | 536–542 | 46 | 662–668 | 67 | 788–794 |
| 5 | 76– 82 | 26 | 542–548 | 47 | 668–674 | 68 | 794–800 |
| 6 | 82– 88 | 27 | 548–554 | 48 | 674–680 | 69 | 800–806 |
| 7 | 174–180 | 28 | 554–560 | 49 | 680–686 | 70 | 806–812 |
| 8 | 180–186 | 29 | 560–566 | 50 | 686–692 | 71 | 812–818 |
| 9 | 186–192 | 30 | 566–572 | 51 | 692–698 | 72 | 818–824 |
| 10 | 192–198 | 31 | 572–578 | 52 | 698–704 | 73 | 824–830 |
| 11 | 198–204 | 32 | 578–584 | 53 | 704–710 | 74 | 830–836 |
| 12 | 204–210 | 33 | 584–590 | 54 | 710–716 | 75 | 836–842 |
| 13 | 210–216 | 34 | 590–596 | 55 | 716–722 | 76 | 842–848 |
| 14 | 470–476 | 35 | 596–602 | 56 | 722–728 | 77 | 848–854 |
| 15 | 476–482 | 36 | 602–608 | 57 | 728–734 | 78 | 854–860 |
| 16 | 482–488 | 37 | 608–614 | 58 | 734–740 | 79 | 860–866 |
| 17 | 488–494 | 38 | 614–620 | 59 | 740–746 | 80 | 866–872 |
| 18 | 494–500 | 39 | 620–626 | 60 | 746–752 | 81 | 872–878 |
| 19 | 500–506 | 40 | 626–632 | 61 | 752–758 | 82 | 878–884 |
| 20 | 506–512 | 41 | 632–638 | 62 | 758–764 | 83 | 884–890 |
| 21 | 512–518 | 42 | 638–644 | 63 | 764–770 |  |  |
| 22 | 518–524 | 43 | 644–650 | 64 | 770–776 |  |  |

CHART 1

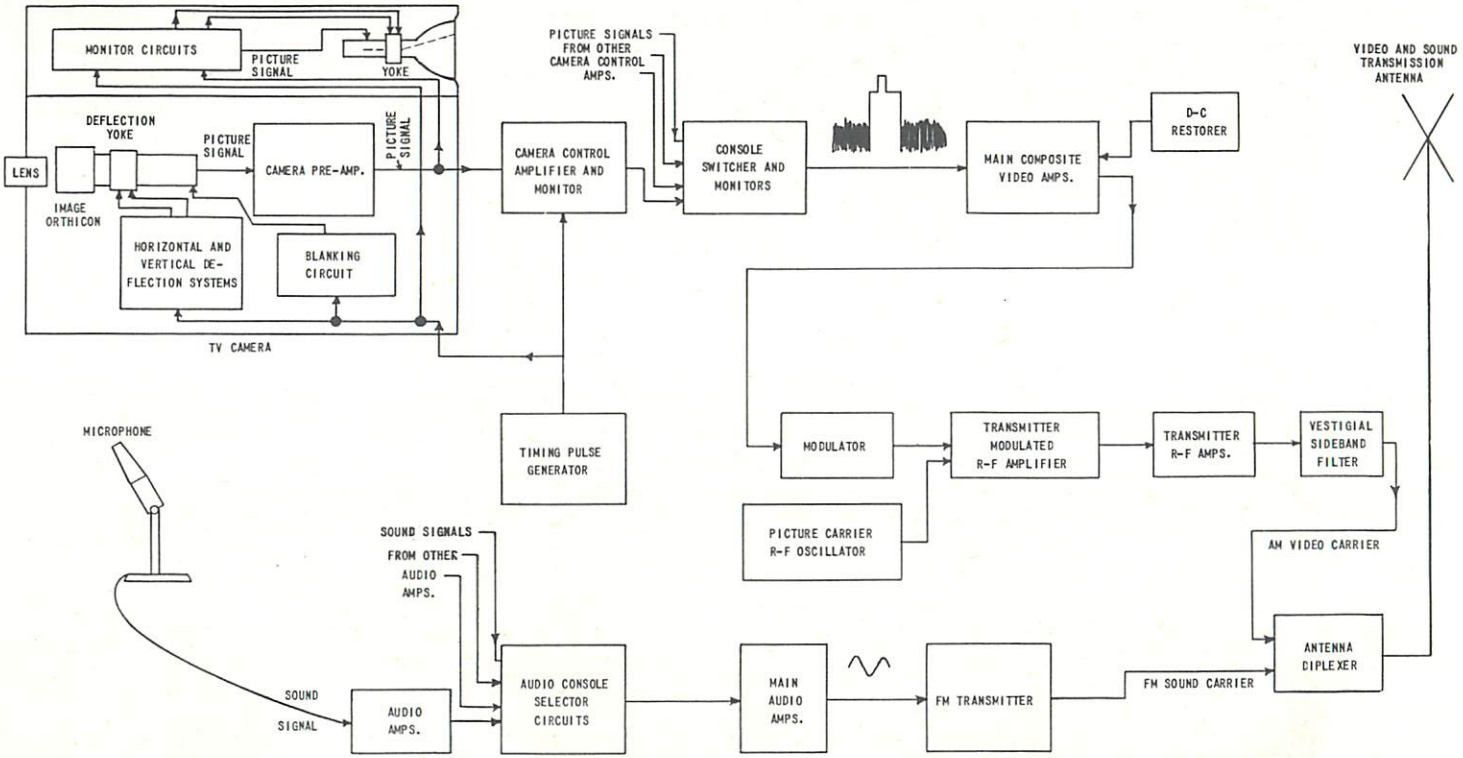

MONITOR CIRCUITS
PICTURE SIGNAL
YOKE
DEFLECTION YOKE
LENS
IMAGE ORTHICON
PICTURE SIGNAL
CAMERA PRE-AMP.
PICTURE SIGNAL
HORIZONTAL AND VERTICAL DE-FLECTION SYSTEMS
BLANKING CIRCUIT
TV CAMERA
CAMERA CONTROL AMPLIFIER AND MONITOR
PICTURE SIGNALS FROM OTHER CAMERA CONTROL AMPS.
CONSOLE SWITCHER AND MONITORS
MAIN COMPOSITE VIDEO AMPS.
D-C RESTORER
VIDEO AND SOUND TRANSMISSION ANTENNA
TIMING PULSE GENERATOR
MODULATOR
TRANSMITTER MODULATED R-F AMPLIFIER
TRANSMITTER R-F AMPS.
VESTIGIAL SIDEBAND FILTER
PICTURE CARRIER R-F OSCILLATOR
AM VIDEO CARRIER
MICROPHONE
SOUND SIGNALS FROM OTHER AUDIO AMPS.
SOUND SIGNAL
AUDIO AMPS.
AUDIO CONSOLE SELECTOR CIRCUITS
MAIN AUDIO AMPS.
FM TRANSMITTER
FM SOUND CARRIER
ANTENNA DIPLEXER

FIGURE 1

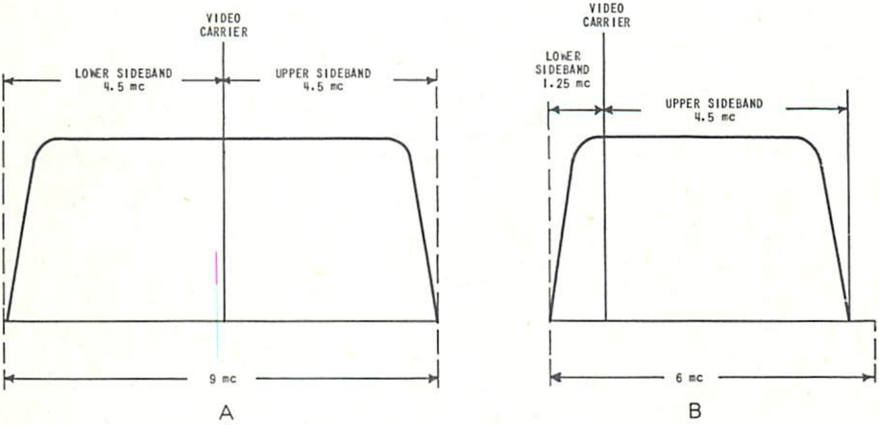


FIGURE 2

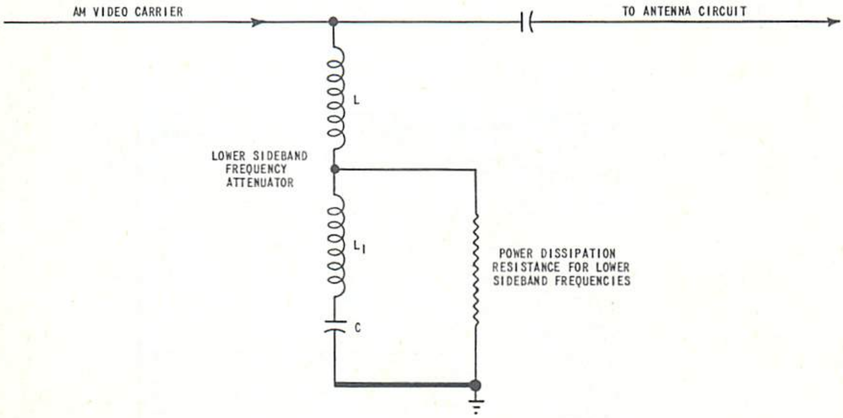

AM VIDEO CARRIER
TO ANTENNA CIRCUIT
L
LOWER SIDEBAND FREQUENCY ATTENUATOR
$L_1$
C
POWER DISSIPATION RESISTANCE FOR LOWER SIDEBAND FREQUENCIES

FIGURE 3

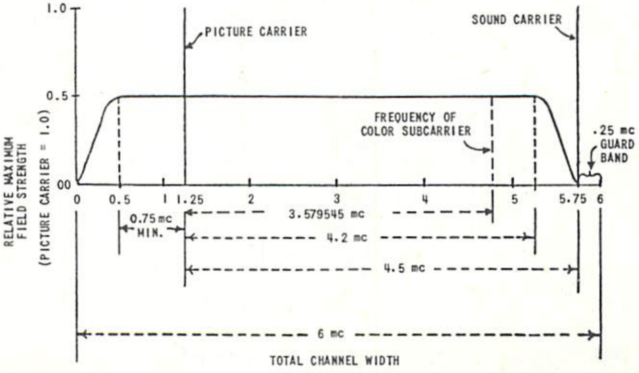


FIGURE 4

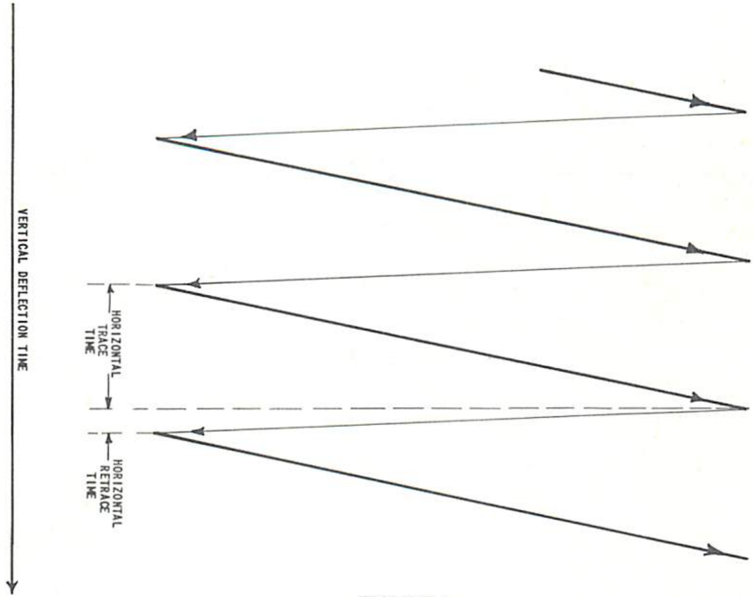
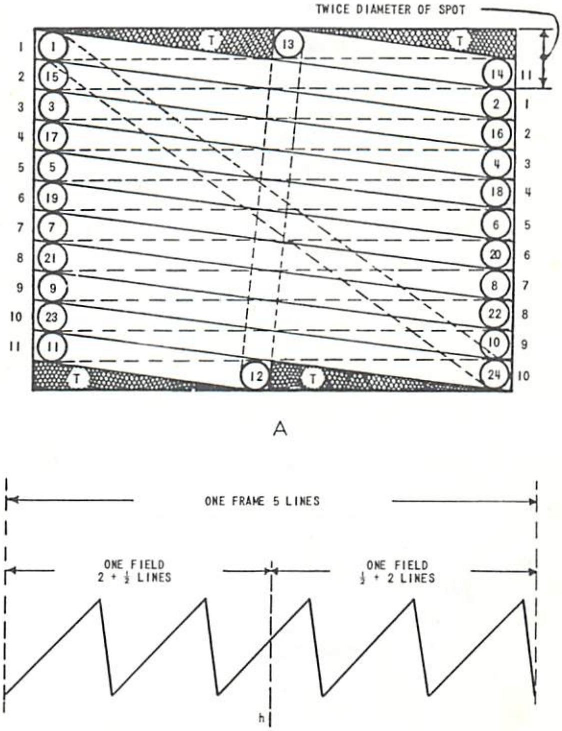


FIGURE 5



A

B

FIGURE 6

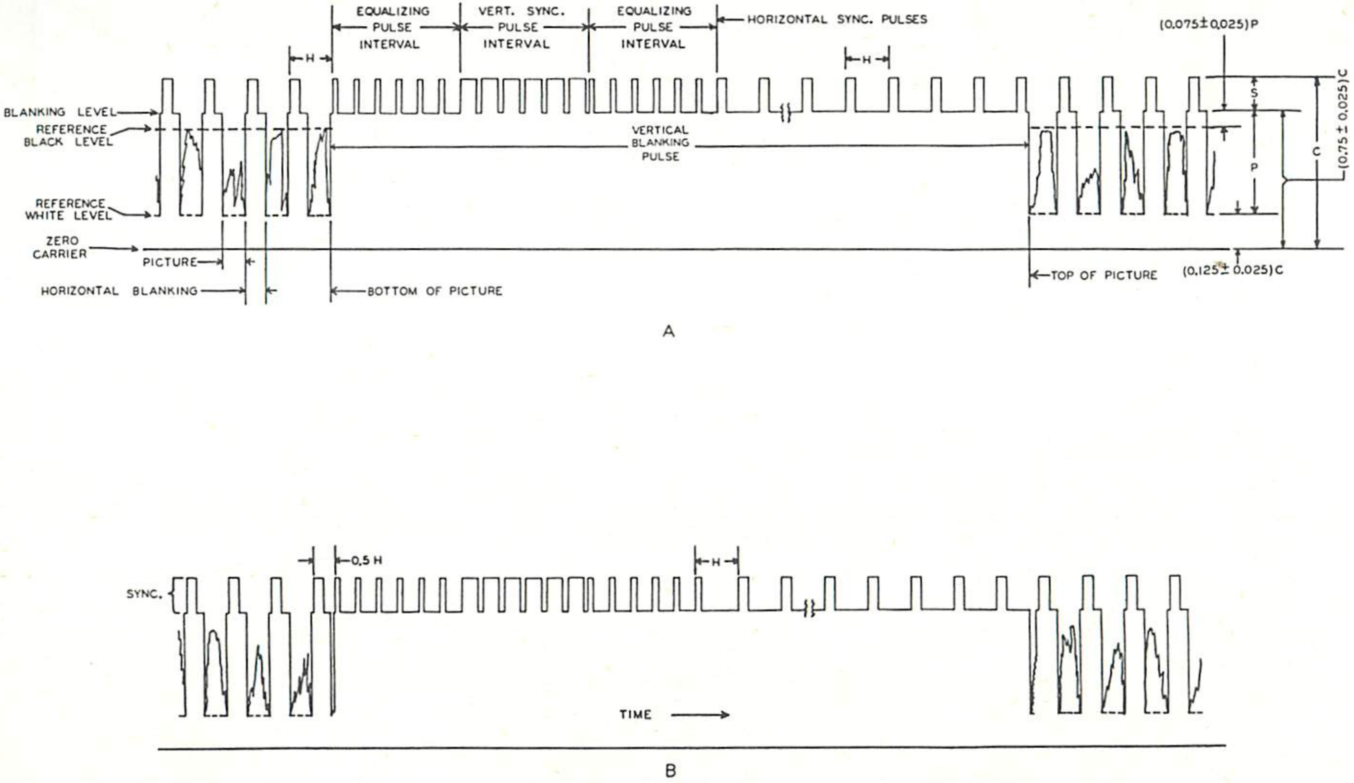

EQUALIZING PULSE INTERVAL
VERT. SYNC. PULSE INTERVAL
EQUALIZING PULSE INTERVAL
HORIZONTAL SYNC. PULSES
H
H
(0.075±0.025)P
BLANKING LEVEL
REFERENCE BLACK LEVEL
VERTICAL BLANKING PULSE
S
P
C
(0.75 ± 0.025)C
REFERENCE WHITE LEVEL
ZERO CARRIER
PICTURE
HORIZONTAL BLANKING
BOTTOM OF PICTURE
TOP OF PICTURE
(0.125 ± 0.025)C
A
0.5 H
H
SYNC.
TIME
B

FIGURE 7

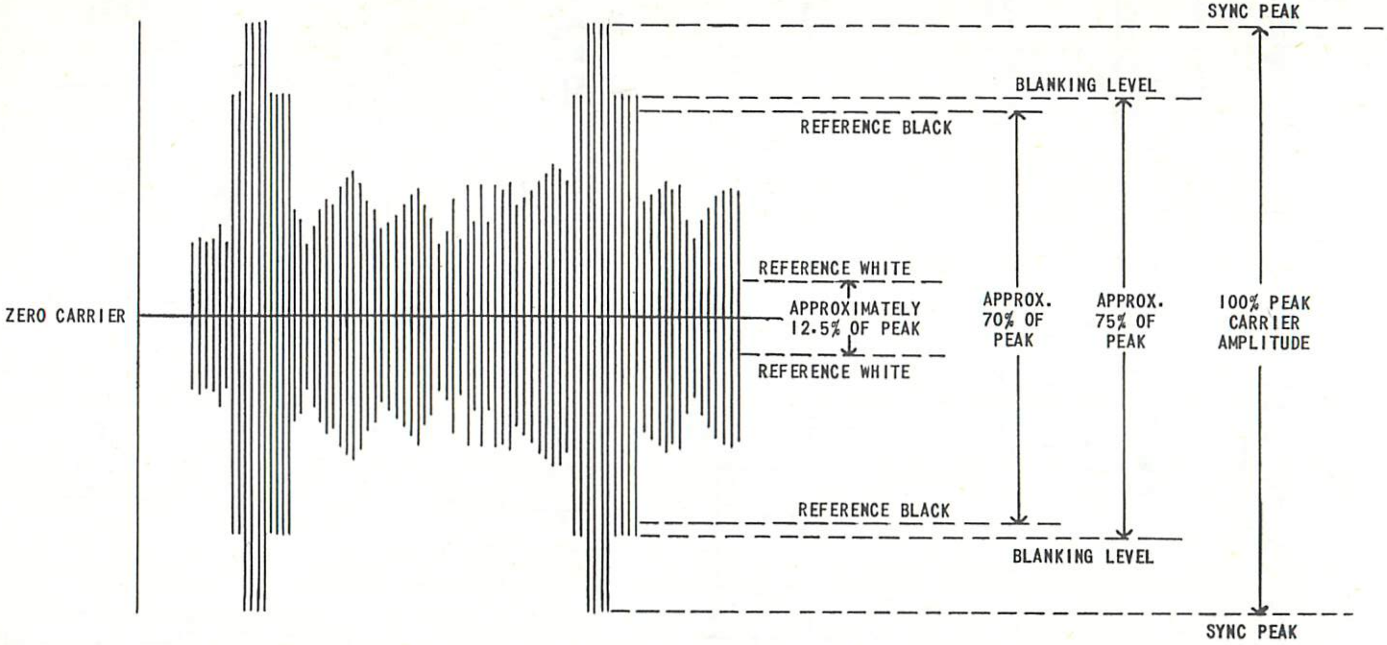

SYNC PEAK
BLANKING LEVEL
REFERENCE BLACK
REFERENCE WHITE
ZERO CARRIER
APPROXIMATELY 12.5% OF PEAK
REFERENCE WHITE
APPROX. 70% OF PEAK
APPROX. 75% OF PEAK
100% PEAK CARRIER AMPLITUDE
REFERENCE BLACK
BLANKING LEVEL
SYNC PEAK

FIGURE 8

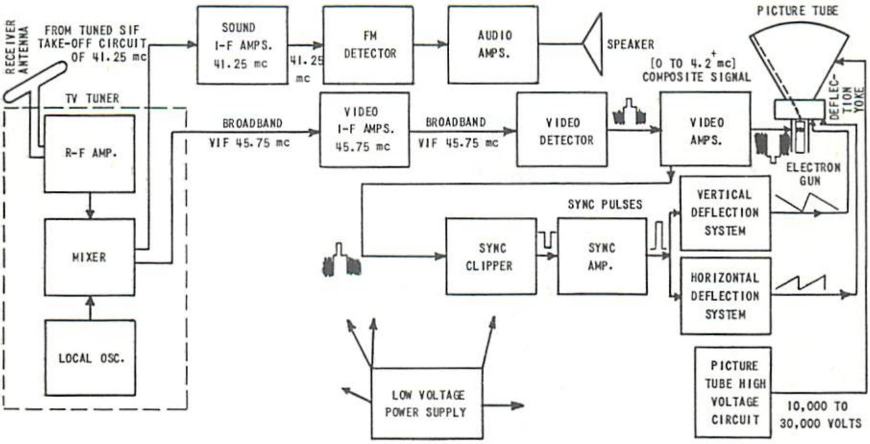


FIGURE 9

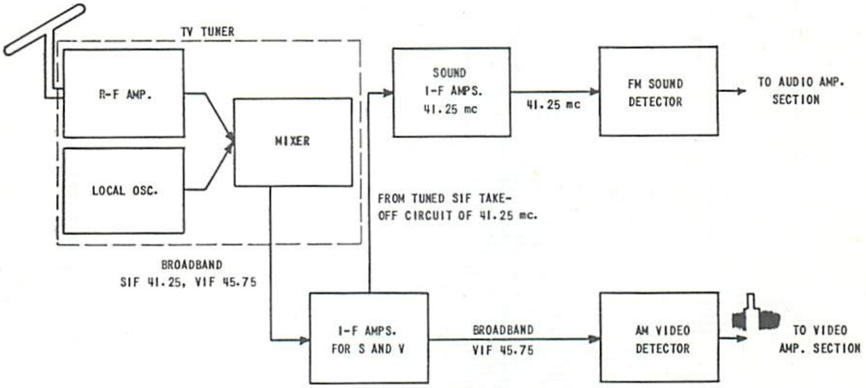


FIGURE 10

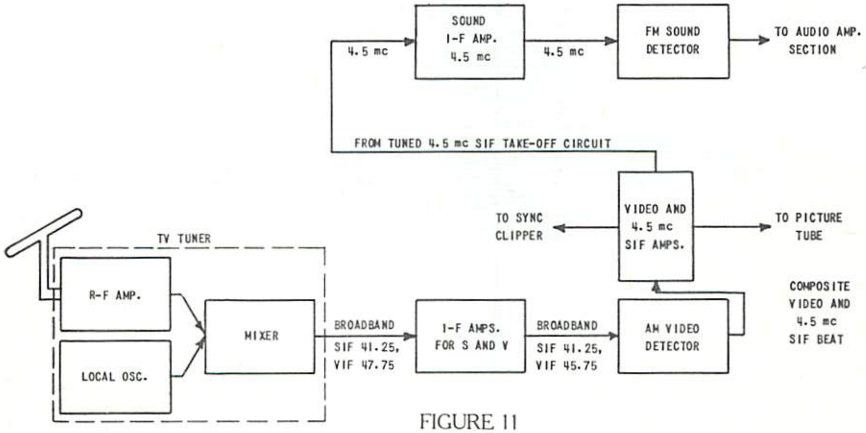


FIGURE 11

T2

## FROM OUR *Director's* NOTEBOOK

### LUCK

Our luck is to a great extent a matter of our own choosing. If we get satisfaction out of believing we were born under an unlucky star, then we naturally consider ourselves unlucky. If we get more satisfaction, however, out of meeting our problems and trying to work them out, other people will probably call us lucky. Luck is, therefore, largely a state of mind. The man who faces his problems and does something about them, is usually the one who forges ahead. Use his methods, and you will see how fast your bad breaks turn into good chances for personal achievement.

Yours for success,

W. C. De Vry
DIRECTOR

PRINTED IN U.S.A.